

Additional Simulations for an RPC Detector and Comparison with Other Analyses

S. Wojcicki, T.J. Yang

November 27, 2003

Abstract

In this memo we describe the simulation for an RPC detector with **XORY** readout configuration and the simulation result based on the events generated by **NEUGEN3**. A comparison is made between different analyses using a solid scintillator detector, a liquid scintillator detector and an RPC detector.

1 Further results on an RPC detector

Off-Axis-NOTE-SIM-19[1] described the analysis of the data from an RPC off-axis detector at a site 735km from Fermilab. After the reconstruction of MC events, we developed a number of variables and made cuts on them for the purpose of the rejection of background while keeping a high efficiency for the signal. The most important variables are the total number of hits, the mean number of hits per plane, the fraction of the hits assigned to the electron candidate, the track length and the asymmetry of the hits in the event etc. A likelihood analysis performed on the remaining events after cuts can increase FOM a little bit. This procedure is similar to the scintillator simulations in philosophy. In memo [1], we assumed the RPC detector has **X and Y** readout. The result of that analysis is listed in Table 1 (next page), where the Figure of Merit (FOM) is defined as the number of signal events divided by the square root of the number of background events.

By ignoring the Y readout in the odd planes and the X readout in the even planes, a detector with **X or Y** readout configuration could be studied. This analysis is comparable to the simulation of a scintillator detector with no pulse height configuration[3]. The result is listed in Table 2:

	signal	numu_NC	numu_CC	Beam_nue
before cuts	643.0	6935.1	10003.9	468.1
after cuts	238.8 ± 2.3	16.3 ± 1.5	3.3 ± 0.4	26.4 ± 0.3
efficiency or rejection	0.371	2.3e-3	3.3e-4	5.6e-2
FOM = 35.2±0.7				

Table 1: Numbers of signal and background events for **X and Y** readout configuration

	signal	numu_NC	numu_CC	Beam_nue
before cuts	642.9	6958.3	10014.4	469.0
after cuts	211.8 ± 1.8	17.9 ± 1.4	4.9 ± 0.5	23.6 ± 0.2
efficiency or rejection	0.329	2.6e-3	4.9e-4	5.0e-2
FOM = 31.1±0.6				

Table 2: Numbers of signal and background events for **X or Y** readout configuration

The analyses shown above were based on the events generated by NEUGEN2. We also studied the performance of an RPC detector with XANDY readout configuration based on the events generated by **NEUGEN3** which included the coherent pion production. The coherent produced pion was expected to be a significant background. The cuts were reoptimized in order to get the highest FOM.

	signal	numu_NC	numu_CC	Beam_nue
before cuts	639.4	6899.8	10110.7	477.2
after cuts	214.5 ± 1.8	21.9 ± 2.8	3.1 ± 0.6	24.6 ± 0.3
efficiency or rejection	0.335	3.2e-3	3.1e-4	5.2e-2
FOM = 30.4±0.9				

Table 3: Numbers of signal and background events based on events generated by **NEUGEN3**

It was found that among the 21.9 NC background events, 5.8(26%) of them came from the coherent pion generation. Thus it appears that the decrease in FOM in NEUGEN3 is consistent with it being entirely due to the additional background from the coherent pi0 production.

We have visually inspected some of the events from the residual NC background. It appears that additional background reduction

might be possible with significantly more sophisticated algorithm, utilizing mainly geometrical information for the conversion of the second gamma from the pi0. Such studies should be pursued for both detector technologies before one decides on technology to be used.

2 A Comparison of different analyses

Several independent analyses were performed using different kinds of detector and configuration. In [2] Camilleri et al studied an RPC off-axis detector performance as a function of sampling frequency. Both **X and Y** and **X or Y** readout configurations were discussed. In [3] Litchfield et al studied a solid scintillator off-axis detector performance and in [4] they studied a liquid scintillator off-axis detector performance. It's interesting to compare different analyses especially the RPC detector with **X or Y** configuration with the scintillator detector with no pulse height configuration. Unless stated explicitly in the table, all the analyses would be under the following assumptions:

- Far detector is 735 km far from Fermilab with a transverse distance 10 km.
- The oscillation parameters are:

$$\sin^2 2\theta_{23} = 1.0, \sin^2 \theta_{13} = 0.1 \text{ and } \Delta m_{atm}^2 = 2.5 \times 10^{-3} eV^2$$

- The material between active planes is $0.3X_0$ for the RPC analyses and $0.36X_0$ for the scintillator analyses.
- The strip width in the scintillator analyses[3,4] is 4cm compared with 5cm in the RPC analysis of Yang et al [1] and 3cm in the RPC analysis of Camilleri et al [2].

Detector	Analysis	NEUGEN	Variation	ν_e efficiency	FOM-1	FOM-2	FOM-2 opt
Solid Scintillator	Litchfield et al [3]	2	with ph	22.9%	31.0 ± 0.5	12.3	
		2	no ph	25.1%	29.4 ± 0.5	12.6	
	Yang et al [1]	2	XANDY	37.1%	35.2 ± 0.7	14.2	15.2 ± 0.1
		2	XORY	32.9%	31.1 ± 0.6	13.2	14.6 ± 0.1
RPC	Camilleri et al [2]	3	XANDY	33.5%	30.4 ± 0.9	13.2	14.1 ± 0.1
		2	XANDY	35%	35.0	13.0	
	Litchfield et al [4]	2	XORY		32.6		
		2	with ph	20.6%	29.0 ± 0.5	10.4	
Liquid Scintillator	Litchfield et al [4]	3	with ph	20.3%	27.1 ± 0.5	10.2	
		3	820km	19.9%	25.3 ± 0.4	9.0	
		3	820km and $\Delta m^2 = 2.0 \times 10^{-3} eV^2$	19.4%	20.1 ± 0.4	8.0	

Table 4: Comparison of different analyses

Two different FOMs were defined as:

$$\text{FOM-1} = \frac{\text{Number of signal events}}{\sqrt{\text{Total number of background events}}}$$

$$\text{FOM-2} = \frac{\text{Number of signal events}}{\sqrt{\text{Number of signal events} + \text{Total number of background events}}}$$

Optimization on FOM-1 will find the maximum sensitivity for the signal while optimization of FOM-2 will give highest measurement precision of the signal. The values quoted in FOM-2 column represent calculation of FOM-2 when the analysis is optimized for FOM-1. In the last column we quote the value for the analysis optimized for FOM-2.

One might make several observations about the results quoted in the Table 4:

- a) The two RPC analyses are relatively consistent.
- b) Within the statistics the gain from pulse height in a scintillator detector (1.6 in FOM-1) is comparable or somewhat smaller than gain from XANDY configuration for RPC's (2.4-4.1).
- c) XANDY configuration for RPC's appears to give a somewhat better FOM-1 than the scintillator based detector. If this conclusion is indeed valid, it is not clear whether that is fundamental to the detector or the result of somewhat different analyses.
- d) The FOM-2 values for the scintillator detector are significantly lower than for the RPC detector. An important question for the eventual choice of the detector technology is to see whether this difference persists for analyses optimized for FOM-2.

Acknowledgement

The study on **X or Y** configuration was based on the code modified by Josh Thompson.

References

- [1] S.Wojcicki, T.J.Yang, A Study of the dependence of an Off-axis Detector Performance on the strip width and track finding/fitting parameters, Off-Axis-NOTE-SIM-19.
- [2] L.Camilleri, A.Para, A Study of an Off-axis Detector Performance as a Function of Sampling Frequency, Off-Axis-NOTE-SIM-12.
- [3] P.Litchfield, L.Mualem, D.Petyt, Simulation of a Solid Scintillator Off-axis Detector, Off-Axis-NOTE-SIM-23.
- [4] P.Litchfield, L.Mualem, D.Petyt, Simulation of a Liquid Scintillator Off-axis Detector, Off-Axis-NOTE-SIM-24.